

Mullard Radio Astronomy Observatory



Cavendish Laboratory
Cambridge

Radio Astronomy at Cambridge

Radio Astronomy is the study of celestial objects by means of the radio waves they emit. By observations with radio telescopes we can learn more about the Sun, Moon and Planets; about our Galaxy (the Milky Way system) and about radio galaxies and quasars. The radio waves from some of these have been travelling to us for thousands of millions of years and convey information on what the Universe was like at that time in the past.

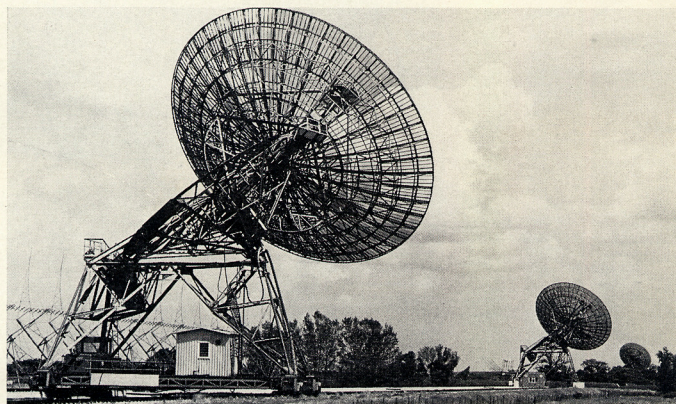
The Cavendish Laboratory was one of the first to explore this field of research and work has continued since 1946 under the direction of Professor Sir Martin Ryle, F.R.S. The observatory was initially on the outskirts of Cambridge, but in

1957, through the generosity of Mullard Limited and with support from the Science Research Council, the Mullard Radio Astronomy Observatory was built at Lord's Bridge, five miles south-west of Cambridge.

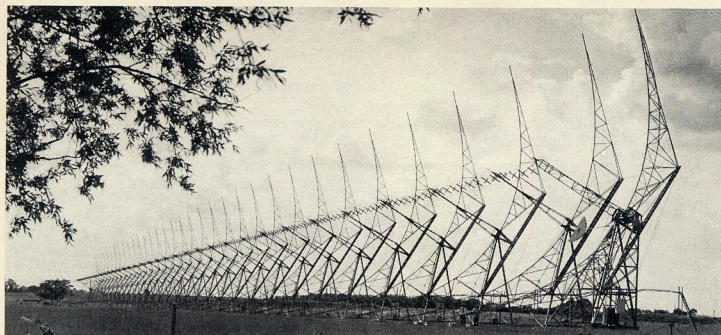
Equipment

A radio telescope consists of a directive aerial system connected to a highly sensitive radio receiver. The ability to separate two sources lying in nearly the same direction depends on the size of the aerial and the operating wavelength; the larger the aerial and the shorter the wavelength the finer is the detail which can be mapped. The use of very short wavelengths, however, means that the aerial must be built with great precision and correspondingly great cost, if indeed it can be built at all. A more economical technique has therefore been developed

The three aerials of the One-Mile Radio Telescope. These 60 ft. dishes are equatorially mounted and continuously track any chosen point in the sky. The reflecting surface is of aluminium mesh. The rail track on which the nearer aerial moves is accurate to $\frac{1}{4}$ inch over half a mile.



The fixed aerial of the radio source interferometer. This trough reflector is formed by stretching stainless steel wires over 34 parabolic frames. It measures 1450 ft. by 65 ft. and can be used in conjunction with a smaller movable aerial 2300 ft. away. It may be tipped to any elevation by electric motors mounted on each tower.



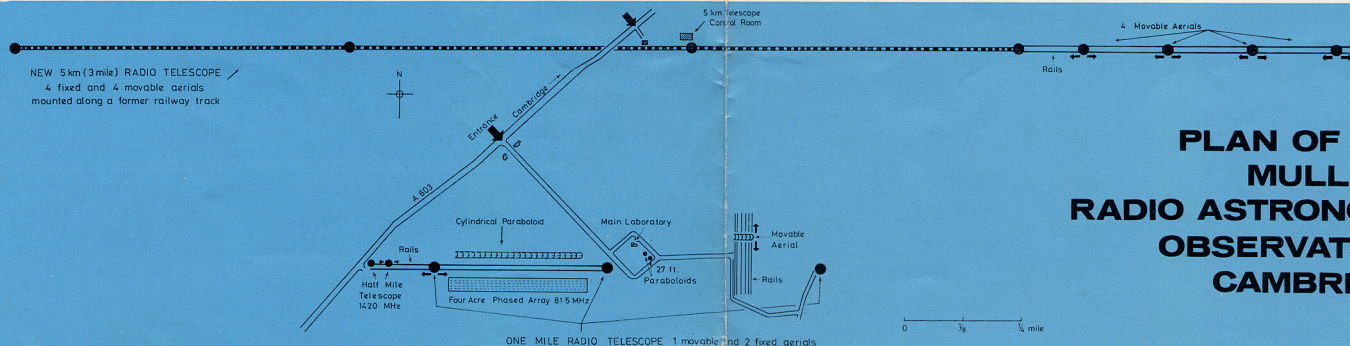
at Cambridge. It is based on the use of two or more small aerials which are moved about so that they occupy successively the positions of the individual components of a much bigger aerial. By combining in a computer the observations made in each of these positions, a resolving power equal to that of the bigger aerial is achieved. The sensitivity of the telescope is also considerably increased although not quite to the same extent.

Several telescopes using this "aerial synthesis" principle have been operating at the M.R.A.O. since 1957. One of these consists of a fixed reflector 1450 ft. by 65 ft. together with a smaller reflector which may be moved along a north-south rail track 1000 ft. long. The instrument was designed to survey the northern sky, and is equivalent to two parabolic reflectors 750 ft. in diameter.

Another instrument, the One-Mile Telescope, was completed in 1964; it

consists of three reflectors, 60 ft. in diameter, two being fixed and one movable. They are arranged on an east-west axis and can follow any point in the sky. Because of the rotation of the earth two rings of a much larger equivalent aperture are built up every twelve hours. The position of the movable aerial on the rail track is then altered, and further rings are filled in on successive days until a resolving power is achieved equal to that of a parabolic reflector one mile (1.6 km) in diameter. This telescope can observe at two wavelengths simultaneously and takes no longer to survey a given area of sky than would the complete large aerial. The telescope is used for high-resolution studies of radio sources and also for "deep" surveys of very faint sources.

Over the last few years further large telescopes have been completed. The Half-Mile Telescope consisting of two 30 ft. dishes and equivalent to an instrument $\frac{1}{2}$ -mile (0.8 km) in diameter



PLAN OF THE MULLARD RADIO ASTRONOMY OBSERVATORY CAMBRIDGE

is being used at a wavelength of 21 cm to study the structure of radio sources and nearby galaxies; this telescope is equipped with a multi-channel receiver for measuring line radiation from neutral hydrogen. Another instrument, the Four-Acre array, consists of a phased array operating at 3.7 m wavelength, and it was built for studying the scintillations of small-diameter radio sources; it was with this telescope that Pulsars were first discovered in 1967.

Another large instrument, the Five-Kilometre Telescope, is to be completed in 1971; it consists of 4 fixed and 4 movable aerials and it will have the same resolving power as a fully-steerable antenna 5 km (3 miles) in diameter.

Fields of Research

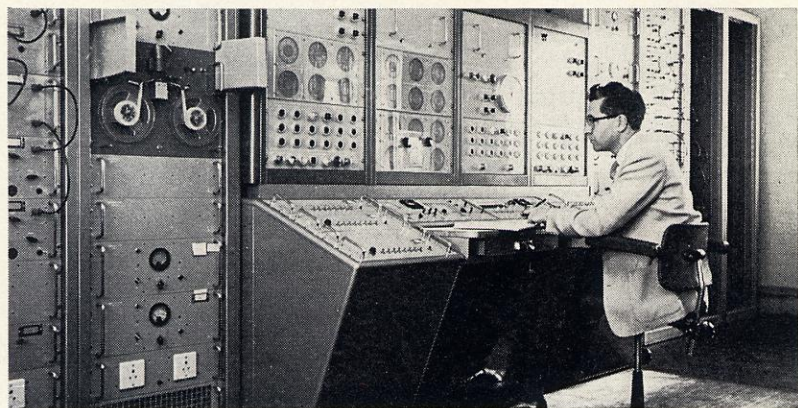
(a) Extragalactic Radio Sources

Most radio sources lie beyond our Galaxy and are associated with very distant galaxies, the "radio galaxies" or else with quasi-stellar radio sources, the "quasars". These objects represent by far the greatest concentrations of energy

It is known that the emission from most radio sources originates in "synchrotron" radiation from highly energetic electrons spiralling in magnetic fields, but it is only by high-resolution studies of the structure of radio sources that the remarkable physical processes occurring within them can be understood. It is for this purpose that the Five-Kilometre Telescope has been designed. The One-Mile Telescope operating at a wavelength of 6 cm has a beamwidth of 6 seconds of arc, and this is already sufficient to reveal the structures of many radio galaxies. The positions of more compact sources can be measured to better than 1 second of arc. Nearby normal galaxies are also studied, and the distributions and velocities of clouds of gas within these galaxies can be investigated with the Half-Mile Telescope.

(b) Galactic Radio Astronomy

There are many discrete radio sources within our own Galaxy. Clouds of hydrogen ionized by hot stars are powerful radio sources at short wavelengths. Radio emission also occurs from the remains of supernova explosions: the



The controls of the One - Mile Radio Telescope. In operation the three aerials are controlled automatically by the programme tape and reader on the left of the picture. The dials on the console show in which direction the dishes are pointing. The receivers are grouped in racks on each side of the console.

known in the Universe and an understanding of them demands new developments in physical theory. One quasar, 3C9, is receding from us at 80% of the velocity of light.

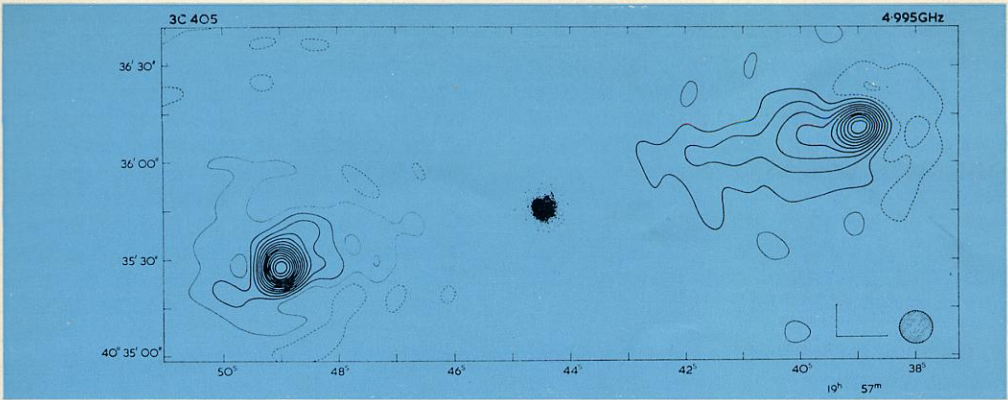
Much of the study of radio sources is based on surveys of the sky carried out at Cambridge. The 3C catalogue lists the brightest 471 sources in the sky, and the 4C catalogue, completed in 1964, lists nearly 5000 sources 90% of which had never been observed before. Deep surveys (5C) of small regions of sky reaching to sources 100 times fainter still have been carried out with the One-Mile Telescope, and these have revealed the most distant objects ever detected by Man; these surveys have provided further strong evidence for an evolutionary theory of the Universe.

particles and shock waves produced by the explosion radiate as they travel through the interstellar medium.

Cosmic ray electrons within the Galaxy emit radio waves as they interact with the galactic magnetic field. This background radiation has been studied at the M.R.A.O. at a number of frequencies, and a receiver was installed in the UK2 earth satellite to measure galactic radiation at very low frequencies above the ionosphere.

(c) Pulsars

One of the most remarkable scientific discoveries of recent times is that of celestial sources emitting pulses of radio waves; some have periodicities as short as 1/30 sec, others up to 4 sec, and the regularity of the pulses is comparable with that of the best clocks. This



Contour map of the radio galaxy Cygnus A observed with the One-Mile Telescope at 4.995 GHz. The radio waves come from two compact regions each about 200,000 light years from the parent galaxy; the energy associated with this source is equivalent to the total annihilation of 1,000,000 stars.

discovery, made at the M.R.A.O. in 1967, led to detailed studies by observatories throughout the world and to theories of the nature of the pulsating stars, or "Pulsars", which emit these signals.

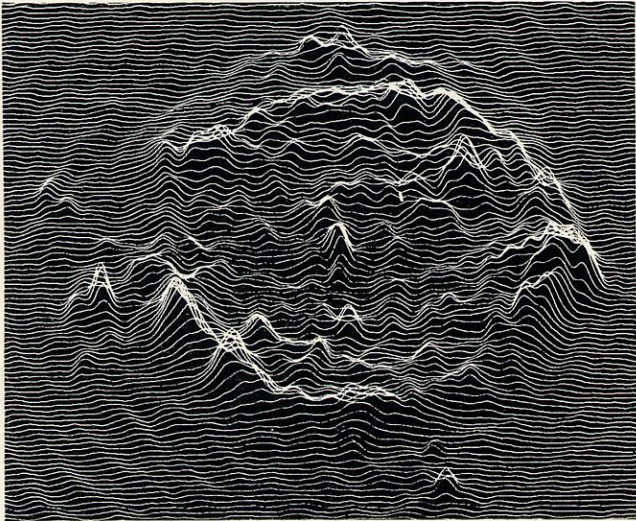
It seems likely that pulsars represent the final stage in the evolution of a star, when it collapses into a body only a few km in diameter with a density of 10 million million gm/cc. The collapse may be associated with a supernova event which leaves behind a collapsed "neutron star" spinning at high speed. Pulsars may be the source of cosmic rays, and their further study may give information on the properties of matter at very high densities.

The present studies at Cambridge include searches for new pulsars as well as long-term observations of known ones.

(d) Solar System

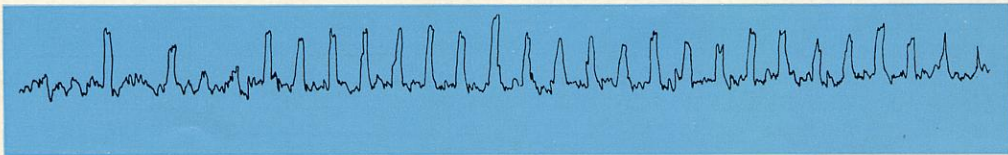
The Moon and Planets emit radio waves simply because they are warm objects, and the surfaces and atmospheres of these bodies are investigated by mapping this radio emission. The radiation belts of Jupiter have also been studied in this way.

Radio waves from distant sources pass through the Solar System before reaching the Earth, and the scattering of these waves by the interplanetary medium provides a way of studying the Solar Wind and its outward motion from the Sun. This scintillation of small-diameter radio sources, first noticed at the M.R.A.O., is being used to investigate small-scale structure in radio-galaxies and quasars.



Profiles of the radio source Cassiopeia A observed with the One-Mile Telescope at 4.995 GHz. The source is the remains of a supernova within our Galaxy and is about 300 years old.

Signals from CP 1919, the first pulsar to be discovered, observed at 81.5 MHz with the four-acre array. The period of the pulses is 1.337301109 seconds.

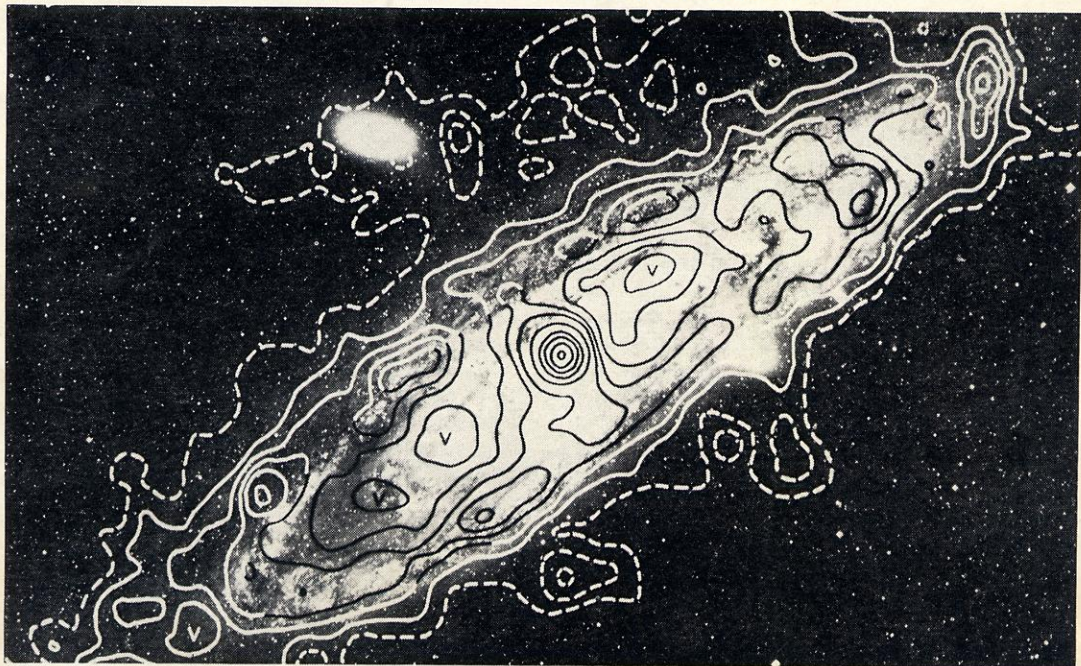


The Future

Radio Astronomy is important both as an intellectual pursuit and also as a training for scientists. Some of the problems with which it deals are fundamental ones, notably the energy sources of pulsars, quasars and radio galaxies, the containment of energetic particles by magnetic fields, and the properties of matter at the extremely high densities existing within quasars and pulsars. Many of these

questions cannot be answered in terrestrial laboratories, and they can only be studied by means of radio astronomy. Other problems are less fundamental but of equal concern: for example techniques developed by radio astronomers have found application in the telecommunications industry. With the present generous support from the Science Research Council, the M.R.A.O. is in a strong position to continue the vigorous advance of Radio Astronomy in Britain.

Contour map of the radio emission from the galaxy M31 (Andromeda) observed at 408 MHz with the One-Mile Telescope; the map is superimposed on a photograph of the galaxy.



Artist's impression of the Five-Kilometre Radio Telescope.

